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OVERCOATING OF INORGANIC ZINC PRIMERS FOR UNDERWATER SERVICE

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ABSTRACT

A study sponsored by **MARAD** under the National Shipbuilding Research Program was undertaken to determine whether overcoating of inorganic zinc primers for underwater service will result in accelerated blistering or disbondment of the topcoat. The study included 5 inorganic zinc primers -- 2 U.S.-manufactured preconstruction type, 1 Japanese preconstruction type, and 2 full-coat type. Two different weathering periods were tested -- **7** days **and** **60** days. Three different topcoats were evaluated, including the Navy MIL-P-24441 system and two commercial epoxy coating systems. Coated test panels were subjected to three different tests to rank susceptibility to blistering: (1) quiescent seawater immersion at a potential of -1.0 volt vs. SCE, (2) quiescent seawater immersion at 25 psi, 150°F, and (3) continuous seawater flow at 18 knots. Interim test results suggest that, for underwater service, overcoating of certain inorganic zinc primers may result in premature blistering or disbondment of the topcoat.

SUMMARY

Based on limited test results obtained to-date, it appears that topcoats tend to blister when applied over inorganic zinc primers versus white-metal steel in underwater service. Also, the results suggest that topcoat blistering/disbondment is more probable on full-coat vs. preconstruction primers. Finally, the

results indicate that inorganic zinc primed test panels weathered for a 60-day period are more prone to topcoat blistering than those weathered for a 7-day period.

INTRODUCTION

A study administered by Avondale Shipyards under MARAD's National Shipbuilding Research Program is in progress, the objectives of which are as follows:

- To determine whether it is necessary, for underwater marine service, to remove inorganic zinc shop primers by abrasive blasting prior to the application of a final coating.
- To determine the surface preparation requirements when overcoating inorganic zinc shop-primed steel for underwater service.
- To determine whether high performance marine coatings are compatible with inorganic zinc primers in underwater service.
- To determine to what extent cathodic protection will affect the performance of coatings applied over inorganic zinc primers.

The following paper summarizes results-to-date of the study.

BACKGROUND

Numerous investigators have discussed blistering problems associated with overcoating inorganic zinc primers (1), (2), (3),

(4). The ability to overcoat inorganic zinc primers in underwater service without incurring subsequent blistering is the primary issue and basis for the subject study. It has been reported that Japanese shipyards are overcoating inorganic zinc preconstruction primers on underwater surfaces without apparent problems. Because of the above-described blistering concerns,the predominant practice in the U.S. is to blast off the preconstruction primer prior to applying the hull coating.*

It has been suggested that the reason the Japanese are able to overcoat without problems is that they 'are using preconstruction primers with very low zinc levels, that are less reactive, and have less of a tendency to liberate hydrogen gas when contacted by water. The lower zinc levels do not provide comparable corrosion protection to those traditionally used in U.S. yards, however, the turnaround time for steel plate fabrication in the Japanese yards is supposedly lower than in U.S. yards (2-3 months vs. 6-9 months), and thus it is believed the additional corrosion protection is unnecessary.

Topcoats with a lower zinc level in the dry film will also tend to be less porous (if the size of the individual zinc particles is equal). Such primers would be less likely to cause the problems associated with zinc primer porosity.

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* The U.S. Navy does not permit overcoating of inorganic zinc primers for underwater service.

EXPERIMENTAL APPROACH

General Test Plan

The general test plan comprised the evaluation of three different epoxy topcoats over each of five inorganic zinc primers. Of primary interest is the effect of different weathering periods for the inorganic zinc primers on the performance of the topcoats. Prepared test panels have been exposed to three different test environments: (1) quiescent seawater immersion at a potential of -1.05 volt vs. SCE, (2) quiescent seawater immersion at 150°F, 25 psi, and (3) flowing seawater at 18 knots.

Coatings Selected For Testing

Table 1 provides a general description of each of the five inorganic zinc primers selected for testing. Table 2 provides a description of the topcoats included in the test program.

Test Panel Preparation

The inorganic zinc primers were applied to ASTM A-36 steel panels, white-metal blasted to obtain a surface profile between 1-2 mils. The nominal panel dimensions were 6" x 12" x 1/8" thick for quiescent immersion testing and 5 1/4" x 7 1/2" x 1/2" thick for flow testing.

The inorganic zinc primers were applied by airless spray using an automated application system designed to provide close control of applied film thickness. The system utilized a fixed spray gun with apparatus for moving the test panel by the spray

gun nozzle at a controlled speed. After coating, the dry film thickness on all test panels was determined using an Elcometer magnetic thickness gauge. The average applied coating thickness of the respective inorganic zinc primers was as follows:

Primer #l - 1.0 mil

Primer #2 - 0.7 mil

Primer #3 - 0.8 mil

Primer #4 - 4.2 mils

Primer #5 - 2.1 mils

After application of the zinc primers, all test panels were weathered on the test fences at the Ocean City Research Corporation Sea Isle test site. This test site provides a natural marine atmosphere and is located approximately 300 feet from the ocean. One-half of the test panels were exposed for 7 days, the other half for a period of 60 days in order to evaluate the effect of different weathering times. After weathering, all test panels were lightly sanded with 600 grit silicon carbide paper to remove any zinc corrosion product (white rust).

After sanding, the test panels were topcoated with one of the three epoxy topcoats. The topcoat systems were applied in accordance with manufacturer's directions using hand-controlled airless spray equipment. After coating, all panels were inspected for "holidays" using a wet-sponge, 67.5 volt holiday detector. All holidays were suitably repaired. The panels were allowed to cure for10 days before being placed into **test.**

After topcoating, the dry film thickness of all panels was again determined using the same equipment as described previously. The average applied coating thickness of the respective topcoat systems was as follows:

Coating #1 - 9.6 mils (applied in 2 coats)

Coating #2 - 11.0 mils (applied in 2 coats)

Coating #3 - 9.2 mils (applied in 3 coats)

During application of the topcoats, some blistering problems were encountered. Depending on the particular primer over which the topcoat was being applied, small blisters or pinholes developed almost immediately after topcoating. This problem occurred even with the application, first, of a thin mist coat (0.25 to 0.5 mil) which was allowed to tack up before applying the full coat. The problem was most evident on zinc primers #4 and #5, the two full-coat inorganic zincs included in the program. Little or no blistering was observed over the thinner preconstruction primers.

As an experimental benchmark, the respective topcoats were also applied to white-metal blasted steel test panels. No application problems were encountered on these test panels.

Duplicate test panels of each coating system were prepared for each of the seawater immersion exposure tests. For the flow test, single panels were prepared. The total number of test panels prepared for exposure testing was 165.

Performance Testing

Three different types of exposure tests are being conducted in the study to evaluate the performance of representative top-coats applied over different inorganic zinc primers. These tests include: (1) quiescent seawater immersion at a potential of -1.0 volt vs. SCE (2) quiescent seawater immersion at 25 psi, 150°F and (3) seawater flow at 18 knots.

Seawater Flow At 18 Knots. A single test panel (5 l/4" x 7 1/2" x 1/2" thick) for each weathering/primer/topcoat condition was exposed in the OCRC natural seawater flow channel for a period of 30 days at a velocityof 18 knots. Each panel received a 1" vertical scribe centered on each side.

The natural seawater flow channel is designed to permit velocity testing under flow conditions that are reasonably representative of the flow conditions that would exist over a major portion of a ship's hull -- fully developed parallel, turbulent, high Reynolds Number, seawater flow. The flow channel accommodates comparatively larger test panels, thus tending to minimize edge and/or boundary effects. The width of the channel cross section varies along the length permitting testing at different flow velocities simultaneously. Figure 1 shows the flow channel while Figure 2 shows the method by which test panels are typically mounted in the flow channel.

Seawater flow through the channel is accomplished using a double-suction centrifugal pump powered by a 100 HP motor. The flow rate exceeds 5,000 gpm and is measured using a factory-

calibrated 316 stainless steel orifice plate/differential pressure gauge set-up. The rate of seawater make-up into the channel can be adjusted to control seawater temperature to within 22.5 C and maintained sufficiently high to avoid stagnation or concentration effects.

Quiescent Seawater Immersion @ -1.0 volt. Duplicate test panels (6" x 12" x 1/8" thick) for each weathering/primer/topcoat condition are suspended in 100-gallon plastic tanks filled with fresh seawater. The seawater tanks are continually refreshed at a rate sufficient to effect a complete changeover 3 times a day. The seawater temperature is maintained at 70°F.

A lead wire was attached to each test panel facilitating electrical connection to a zinc anode. Electrical coupling to a zinc anode maintains the test panels at a potential of -1.0 volt versus a saturated calomel electrode. Prior to the start of test, each test panel received a 1/4" radial holiday directly in the center of one side. The planned test duration is 6 months.

Quiescent Seawater Immersion @ 25psi, 150°F. Duplicate test panels are also immersed in seawater maintained at 25 psi, 150°F. Each test panel has a 1" vertical scribe centered on one side. The panels are mounted in PVC racks. The racks are then inserted into a 12-inch diameter PVC pipe which serves as the test chamber. A pump provides seawater make-up while maintaining a positive pressure inside the pipe of 25 psi. The make-up flow is sufficient to effect a complete changeover once a day. The temperature is controlled at 150°F with two thermosensors im-

mersed in the test chamber which are coupled to a nichrome heating element wrapped around a titanium heat exchanger. The seawater is constantly circulated through the heat exchanger to maintain temperature. The planned test duration is 6 months.

Inspection/Evaluation Procedures

During the course of each of the three exposure tests, the test panels are periodically removed, visually inspected, and rated for blistering, disbondment, and/or other forms of deterioration. At the conclusion of each test, the total extent of coating disbondment is determined by making x-shaped cuts with a sharp knife through the coating and lifting all loose or disbonded coating with the point of a knife.

INTERIM RESULTS

Weathering Of Inorganic Zinc Primers Before Topcoating

Visual inspection of the inorganic zinc primed panels after the two different weathering exposures (7 days, 60 days) showed significant differences on only one primer (#1). For system #1, the panels exposed for 60 days exhibited extensive rust-through while those exposed for only 7 days showed no evidence of rust-through. This is shown in Figure 3. Of the three preconstruction primers, Primer #1 had the lowest zinc loading in the dry film.

For the other four inorganic zinc primers, there were only slight, visually detectable differences between the 7-day and 60-

day panels, with the 60-day panels exhibiting slightly more corrosion product (white rust).

Seawater Flow Tests

Table 3 summarizes the extent of topcoat disbondment per panel side after 30 days in test as well as pertinent observations over the course of the tests. As is evident from Table 3, some panels exhibited disbondment within 24 hours after the start of the test.

Table 4 is a condensed version of Table 3, and shows the total area of disbondment by inorganic zinc primer and by individual topcoat. Based on the 30-day results, topcoats applied over Primer #4 showed significantly more disbondment than the other systems. Primer #4 was a 2-component, full-coat system applied at an average thickness of 4.2 mils (the heaviest applied thickness included in the test program). The least amount of topcoat disbondment was observed on Primer #1 an alkyl silicate type preconstruction primer applied at an average DFT of 1 mil. It is noteworthy to point out that the manufacturer of Primer #1 does not recommend overcoating the primer on underwater surfaces.

Of special interest was the comparative topcoat performance over Primer #3 a Japanese preconstruction primer whose manufacturer suggests can be topcoated (without need of wash down or sandsweep) for underwater service. As is evident, significant disbondment occurred on two of the six test panels over 30 days. On both panels, some degree of disbondment was observed within 24 hours after start of the test.

Comparison of the disbondment results by topcoat shows that Topcoat #3, the standard Navy hull coating (MIL-P-24441, Type 1), exhibited the least amount of disbondment over 30 days. For this topcoat, disbondmentoccurred only on those panels primed with Primer #4.

For four out of five primers, the total area of topcoat disbondment was greater on the panels weathered for 60 days versus 7 days. However, additional data is required to establish that this observation is statistically significant with reasonable probability.

An interesting observation is the extensive rusting evident in the areas where the topcoats disbonded. This observation suggests that the zinc primers tend to sacrifice rapidly once exposed to flowing seawater. Furthermore, it suggests that, at holidays, topcoats will be prone to underfilm lifting and disbondment as the zinc coating rapidly dissolves.

Quiescent Seawater Immersion @-1.0 Volt

Through the first 6 weeks of a planned 6-month test, there is no detectable topcoat disbondment on any of the test panels.

Quiescent Seawater Immersion @25 psi, 150°F

Table 5 summarizes the results of weekly inspections made during the first month of testing. Figures 4 and 5 show typical deterioration observed over the first **30** days in test. As is evident from Table 5, blistering/disbondment has been detected on 26 of the 60 panels (43%) in test. Of the 26 panels exhibiting

blistering/disbondment, 18 of the panels were weathered for a 60-day period while the remaining 8 were weathered for a 7-day period. Six of the eight 7-day weathering period panels that exhibited blistering were coated with Primer #4. The results of the flow test discussed previously suggested that there may be a greater tendency for topcoat blistering with Primer #4 than the other primers being tested. Based on the 150°F immersion test results to-date for those panels weathered for 7 days, there also appears to be a greater tendency for blistering of topcoats applied over Primer #4. For the panels weathered for 60 days, blistering has been detected on all topcoats over all primers with one exception (Topcoat #2/Primer #2). No blistering has been detected on the control panels (topcoats applied to white-metal steel).

Comparison of the results-to-date by weathering period suggests that those panels weathered for 60 days are more prone to cause topcoat blistering.. Also, given the lack of any visible blistering on the control panels, the results suggest in general that there is a greater tendency for topcoat blistering over inorganic zinc primers than white-metal steel. The results should be qualified, however, in that the environment of the subject tests is not exactly representative of typical service conditions. It has not been demonstrated that the results of these higher temperature tests will necessarily correlate with exposure under lower temperature conditions. There does appear to be good correlation between these tests and the seawater flow tests.

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1. C. G. Munger, "Inorganic Zinc Coatings, Past Present and Future," Paper No. 70 presented at National Association of Corrosion Engineers (NACE) Forum, Corrosion 75.

2. M.J. Masciale, "Use Zinc Rich Coatings - But Use Them Wisely", Paper No. 80 presented at NACE, Corrosion 75.

3. A. A. Roebuck, "Inorganic Zinc Coatings, Some Disadvantages and Remedies", Paper No. 112 presented at NACE,Corrosion 80.

4. K. B. Tator "Top Coating Zinc Rich Primers", Paper No. 82 presented at NACE, Corrosion 75.

Table 1 - General Description Of Inorganic Zinc Primers Selected For Testing

Coating No.	Description
1	U.S. manufactured, single component, alkyl silicate type preconstruction primer, 35% zinc in the dry film, recommended dry film thickness = 0.6 - 1.0 mil.
2	U.S. manufactured, 2-component, modified zinc silicate preconstruction primer, 86% zinc in the dry film, recommended dry film thickness = 0.6 - 1.0 mil.
3	Japanese manufactured, 2-component preconstruction primer, 50% zinc in the dry film, recommended dry film thickness = 0.5 - 0.7 mil.
4	U.S. manufactured, 2-component, full-coat primer, 56% volume solids, recommended dry film thickness = 3.0 mils.
5	U.S. manufactured, 2-component, full-coat primer, 63% volume solids, recommended dry film thickness = 2.0 mils.

Table 2 - General Description Of Topcoats Selected For Testing

Coating No.	Description
1	Two-component, polyamide-cured high-build coal-tar epoxy, 67% volume solids, recommended application thickness = 5 mils (DF)/coat.
2	Two-component, polyamide-cured epoxy, 56% volume solids, recommended application thickness = 5 mils (DF)/coat. Meets MIL-P-23236, Type 1, Class 1.
3	Two-component, polyamide-cured epoxy, recommended application thickness = 2-3 mils (DF)/coat. Standard U.S. Navy underwater hull coating meeting MIL-P-24441, Type 1.

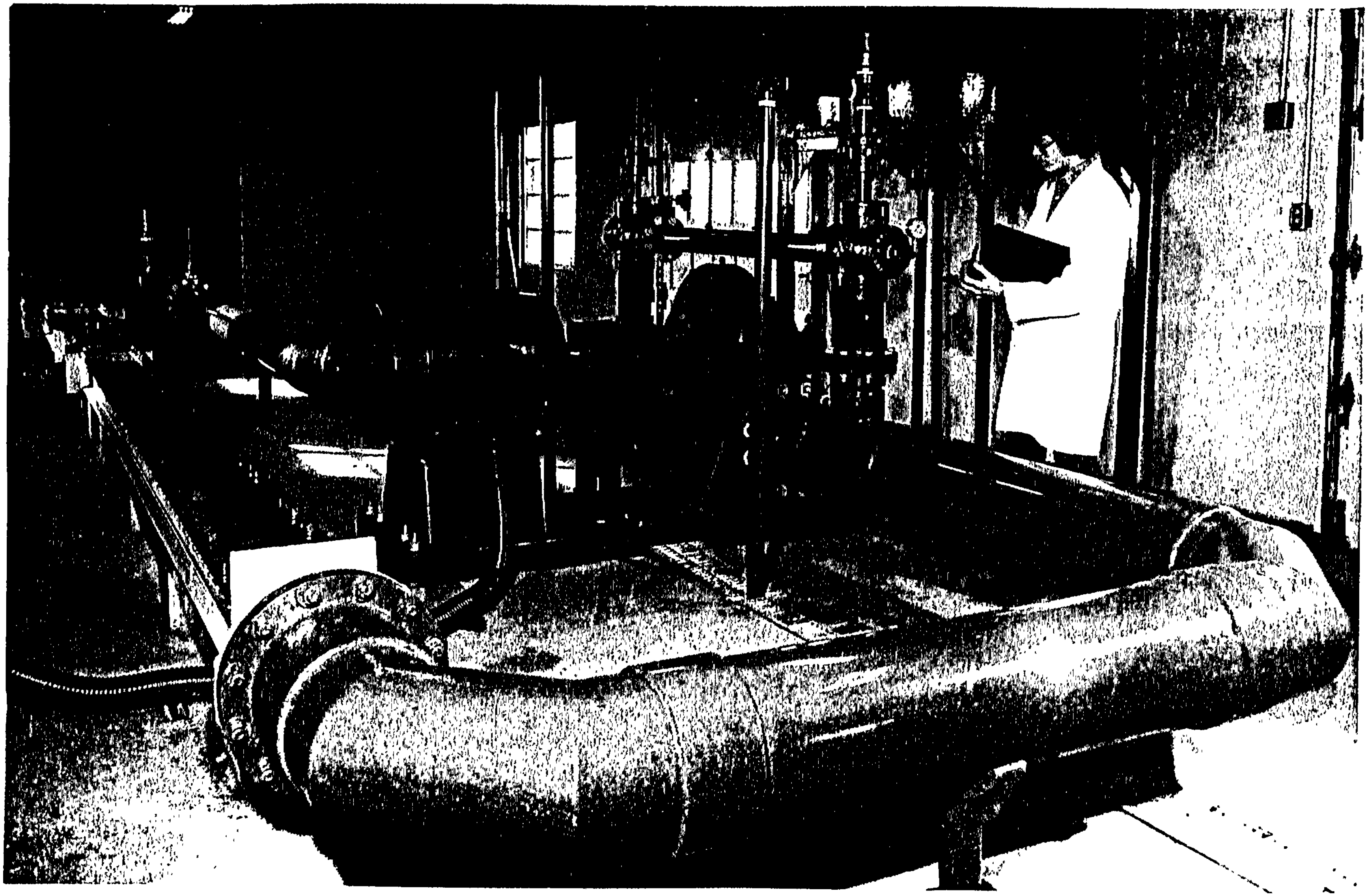

Figure 1 - Seawater Flow Channel

, STEEL CHANNEL

2 T-BOLT

3 TEST PANEL

4 ACRYLIC PLATE

5 STEEL PLATE ,

6 WELD'

7 ELECTRICAL LEAD
CONNECTION

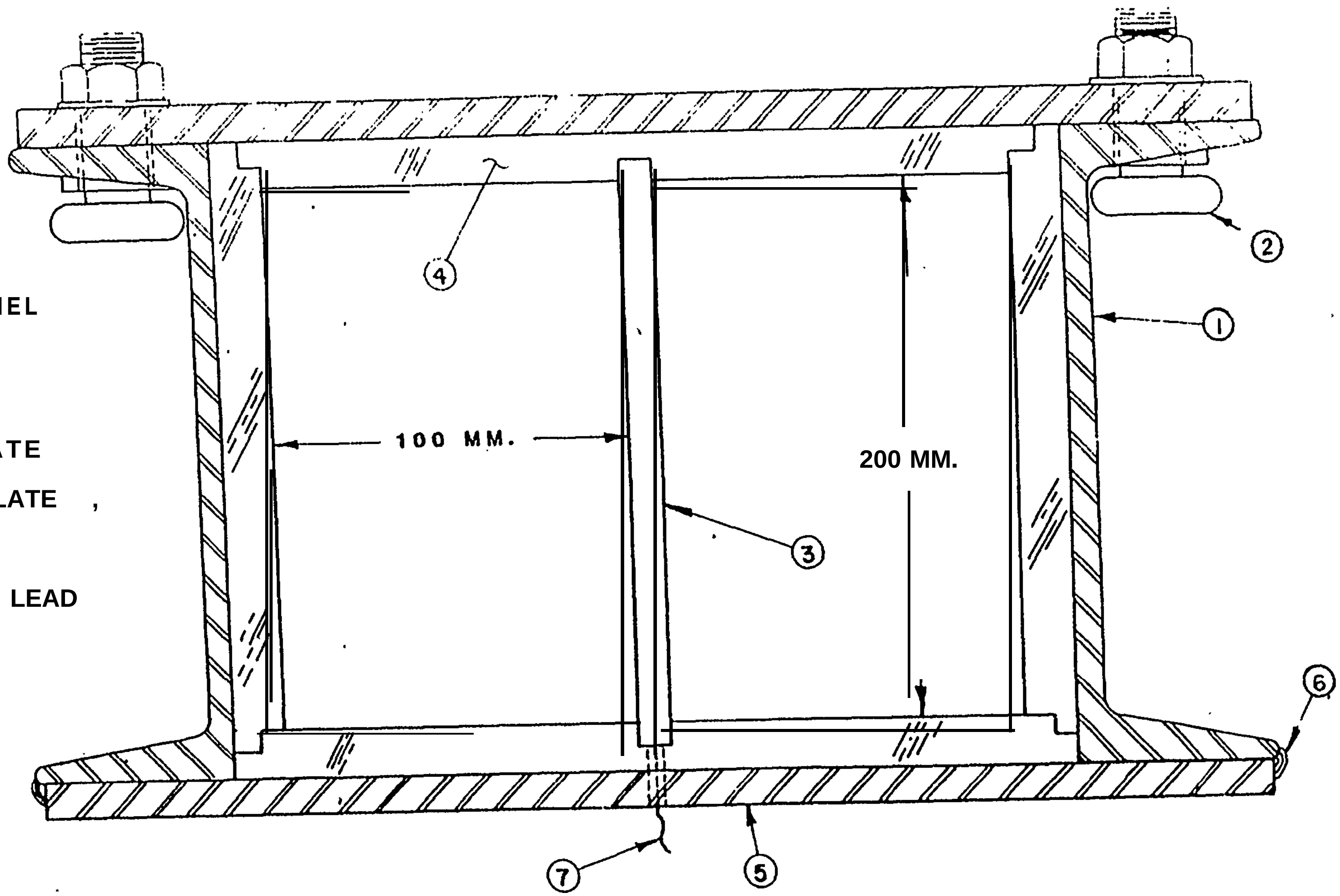

Figure 2 - General Arrangement Of Test Panel
In Seawater Flow Channel

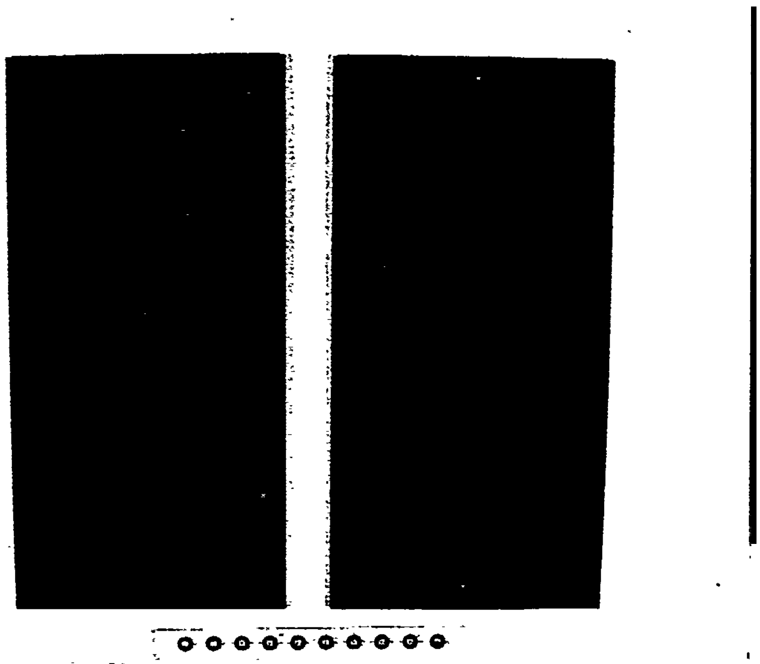

Figure 3 - Primer #1 After 7 (right) and 60 Day (left) Weathering Periods

Table 3 - Summary Of 30-Day Seawater Flow Tests

Inorganic Zinc Primer	Topcoat	Weathering Period	Area of Disbondment, in2 Side #1	Side #2	Total	Remarks
# 1	# 1	7-day	0.00	0.00	0.00	
1	# 2	7-day	0.17	0.42	0.59	
# 1	# 3	‘I-day	0.00	0.00	0.00	
# 1	# 1	60-day	0.10	0.06	0.16	
# 1	# 2	60-day	0.10	0.31	0.41	
# 1	# 3	60-day	0.10	0.12	0.22	
# 2	# 1	7-day	2.00	5.50	7.50	Disbondment detected on side #2 @ 5 days; Disbondment detected on side #1 @ 15 days
#2	# 2	7-day	0.02	0.00	0.02	
# 2	# 3	7-day	0.22	0.18	0.40	
# 2	# 1	60-day	0.00	0.0	0.00	
# 2	#2	60-day	0.09	8.50	8.59	Disbondment detected on side #2 @ 4 hours
#2	# 3	60-day	0.04	0.08	0.12	
# 3	# 1	7-day	0.07	0.02	0.09	
# 3	# 2	7-day	0.00	21.0	21.0	Disbondment detected on side #2 @ 4 hours
# 3	# 3	7-day	0.04	0.04	0.08	
I 3	# 1	60-day	0.00	5.00	5.00	Disbondment detected on side #2 @ 24 hours
# 3	# 2	60-day	0.05	0.07	0.12	
#3	# 3	60-day	0.06	0.09	0.15	

Table 3 (Cont'd)

Inorganic Zinc Primer	Topcoat	Weathering Period	Area of Disbondment, in^2 Side #1	Side #2	Total	Remarks
# 4	#1	‘I-day	8.00	0.00	8.00	Disbondment detected on side #1 @ 12 days
# 4	# 2	'I-day	12.00	0.13	12.13	Disbondment detected on side #1 @ 4 hours
# 4	# 3	'I-day	2.00	2.30	4.30	Disbondment detected on sides #1 and #2 @ 16 days
# 4	#1	60-day	14.00	10.00	24.00	Disbondment detected on sides #1 and #2 @ 16 days
# 4	. # 2	60-day	0.28	0.00	0.28	
# 4	# 3	60-day	0.16	13.50	13.66	Disbondment detected on side #2 @ 24 hours
5	#1	7-day	0.00	0.00	0.00	
#5	#2	7-day	0.08	0.08	0.16	
# 5	# 3	7-day	0.00	0.00	0.00	
# 5	# 1	60-day	0.06	0.00	0.06	
# 5	#2	60-day	20.00	0.00	20.00	Disbondment detected on side #1 @ 4‘hours
#5	# 3	60-day	0.00	0.11	0.11	
Control	#1		0.05	0.00	0.05	
Control	# 2		6.30	0.16	6.46	Disbondment detected on side #1 @ 16 days
Control	# 3		0.11	0.05	0.16	

Table 4 - Total Area Of Disbondment After 30 Day Seawater Flow Tests

Inorganic Zinc Primer	Weathering Period	Area of Disbondment, in2 Topcoat #1	Topcoat #2	Topcoat #3	Total
#1	7-day	0.00	0.59	0.00	0.59
#1	60-day	0.16	0.41	0.22	0.79
#2	7-day	7.50	0.02	0.40	7.92
#2	60-day	0.00	0.59	0.12	8.71
#3	7-day	0.09	21.0	0.08	21.17
#3	60-day	5.00	0.12	0.15	5.27
#4	7-day	8.00	12.13	4.30	24.43
#4	60-day	24.00	0.28	13.66	37.94
#5	7-day	0.00	0.16	0.00	0.16
#5	60-day	0.06	20.00	0.11	20.17
Control	-	0.05	6.46	0.16	6.67
	TOTAL	44.86	69.76	19.20	

Table 5 - Summary Of Inspection Results After 30-Days In Test; Quiescent Seawater Immersion @ 25 psi, 150°F

Inorganic Zinc Primer	Topcoat	Weathering Period	Observations
#1	#1	7-day	No evident deterioration
#1	#2	7-day	No evident deterioration
#1	#3	7-day	No evident deterioration
#1	#1	60-day	Slight blistering on one side of a duplicate panel at 29-day inspection
#1	#2	60-day	Blistering on one side of a duplicate panel at 14-day inspection
#1	#3	60-day	One panel blistered on both sides at 7-day inspection
#2	#1	7-day	No evident deterioration
#2	#2	7-day	No evident deterioration
#2	#3	'I-day	Slight blistering on one side of a duplicate panel at 29-day inspection
#2		60-day	Slight blistering on one side of a duplicate panel at 2l-day inspection
#2	#2	60-day	No evident deterioration
#2	#3	60-day	Slight blistering on one side of a duplicate panel at 21-day inspection
#3	#1	7-day	No evident deterioration
#3	#2	'I-day	Large blisters on one side of a duplicate panel at 7-day inspection
#3	#3	7-day	No evident deterioration
#3	#1	60-day	Both panels progressively blistering, first detected at 7-day inspection
#3	#2	60-day	Heavy blistering of a duplicate panel at 7-day inspection
#3	#3	60-day	Medium blistering on one side of a duplicate panel at 2l-day inspection

Table 5 (Cont'd)

Inorganic Zinc Primer	Topcoat	Weathering Period	Observations
#4	# 1	7-day	One panel blistered at 7-day inspection progressing to 20% disbondment at 21-day inspection, duplicate panel blistered at 29-day inspection
#4	# 2	7-day	Both panels heavily blistered on both sides at 7-day inspection
#4	#3	‘I-day	One panel disbonded 50 and 90% at 7-day inspection, duplicate panel disbonded 75% one side at 7-day inspection
#4	# 1	60-day	Both panels progressively blistering, first detected at ‘I-day inspection
#4	# 2	60-day	Both panels heavily blistered on both sides @ 21-day inspection
#4	# 3	60-day	One panel 5% disbonded at 7-day inspection
# 5	# 1	‘I-day	No evident deterioration
#5	# 2	‘I-day	No evident deterioration
# 5	# 3	‘I-day	No evident deterioration
#5	# 1	60-day	Blistering on one side of duplicate panel @ 21-day inspection
#5	# 2	60-day	Blistering on one side of duplicate panel @ 7-day inspection
#5	# 3	60-day	Blistering on one side of duplicate panel @ 7-day inspection
Control	# 1		No evident deterioration
Control	# 2		No evident deterioration
Control	# 3		No evident deterioration

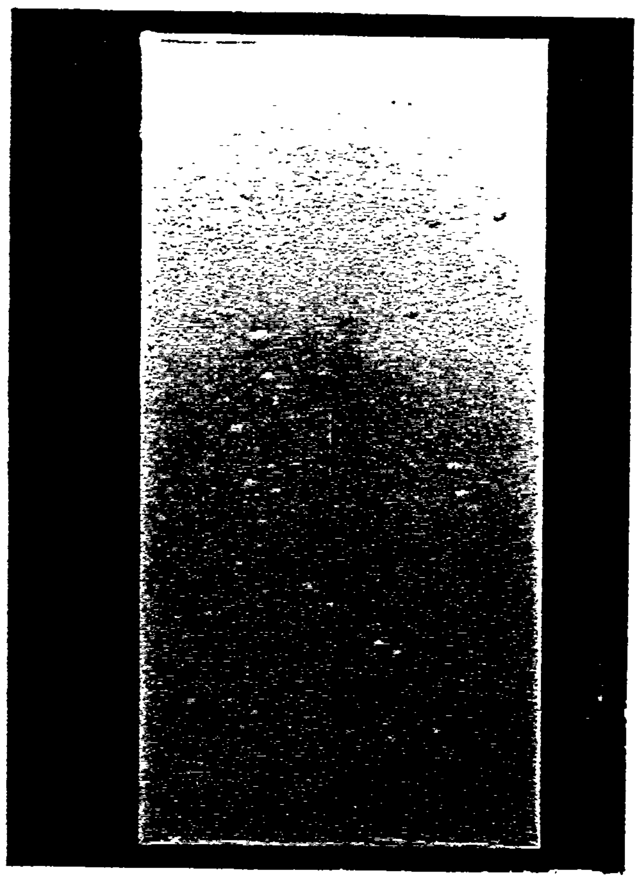

Figure 4 - Topcoat Blistering After 7 Days Exposure To Seawater @ 150°F, 25 psi; Primer #4/Topcoat #2

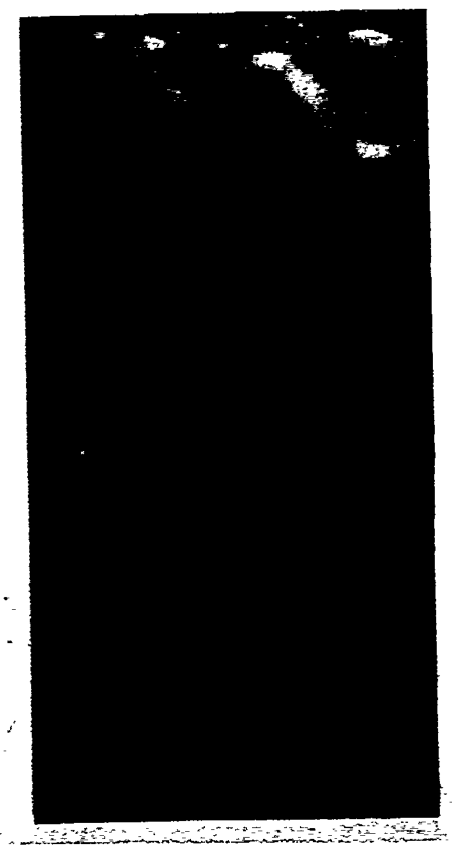

Figure 5 - Topcoat Blistering And Disbondment After 7 Days Exposure To Seawater @ 150°F, 25 psi; Primer #4/Topcoat #3.

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